

Creating Learning through Service Opportunities for Engineering Students: Lessons Learned from a Primarily Undergraduate Liberal Arts Institution

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***Abstract* – The challenge of creating impactful and long-lasting service opportunities for engineering students lies in how to best implement programs in the unique setting of each academic institution. This paper presents a critical reflection of two different models of learning through service opportunities for engineering students that have evolved over the past six years at Loyola Marymount University. In particular, we highlight the history and lessons learned from four different case studies involving both extra-curricular international service projects and course-based service-learning opportunities for engineering students. Overall lessons learned that emerged from our experience include: 1) Students should receive course credit for participating in engineering-oriented service projects; 2) Opportunities for student participation should be vertically integrated throughout the curriculum; 3) Develop and sustain long-lasting relationships with your community partners; 4) Obtain university support for long-term success; 5) Start to conduct assessment of your stakeholders; and 6) Utilize the resources at your institution in order to promote cooperation. We hope that our lessons learned can be used to help guide other primarily undergraduate institutions in implementing service-oriented engineering projects.**

Index Terms - extracurricular international service, course-based service learning, lessons learned, critical analysis

INTRODUCTION

The use of service in engineering education in the United States began in the 1990's and has recently increased based on the need to reconsider the priorities of the professoriate, a desire to improve human conditions to fulfill higher education goals, and to meet the interest and demand of students and faculty across the nation¹⁻⁴. Some examples of exemplary engineering learning

through service programs include: The Engineering Projects in Community Service (EPICS) program developed in 1995 at Purdue University, The Service Learning Integrated throughout a College of Engineering (SLICE) program at the University of Massachusetts Lowell, Engineers Without Borders (EWB), and Engineers for a Sustainable World (ESW). Many other engineering programs are starting to explore ways to offer new and meaningful service experiences for their students.

The main challenge lies in how to best emulate these highly successful and long-standing programs in the unique setting of each academic institution. In our case, how do we draw on best practices while also considering our identity as a private, co-educational, and primarily undergraduate institution in the Jesuit and Marymount traditions? Service to others and the promotion of social justice are at the core of the institutional mission of Loyola Marymount University (LMU). Service is seen as a vehicle to allow our students to grow in their disciplines as whole, well-rounded individuals committed to social justice and improving the human condition. We believe that student service can make a positive impact both on the community and on the students themselves. By engaging in community-based learning, our engineering students are challenged to identify their civic responsibility toward others by seeking ways to integrate their professional development with an ethos of social responsibility.

The LMU Seaver College of Science and Engineering defines itself by its dedication to serving students through transformative teaching, hands-on mentoring, and opportunities for research, service, and community engagement. The college values a community of students, faculty, and staff, diverse in background as well as outlook, working together to serve both the university and society at large. The college's commitment to the Jesuit principle of whole-person education creates a stimulating environment that fosters creativity, leading to innovation in the discovery of truth and problem solving for the global benefit of humanity. The college houses three engineering departments (Civil Engineering and Environmental Science, Electrical Engineering and Computer Science, and Mechanical Engineering) with 478 undergraduate and 127 graduate students earning bachelor's and master's degrees under the direction of 25 tenured and tenure-track faculty. A total of 19% of the engineering undergraduates are Hispanic or Latino, 15% are Asian, 8% are Multi-race, 3% are Black or African American, 45% are White, and 10% are international. Females comprise 25% of the engineering undergraduates.

No engineering-oriented service programs existed at LMU prior to 2008. If engineering students did engage in service projects, they were organized by the LMU Center for Service and Action (CSA) or Campus Ministry offices in the form of cultural and faith-based service immersion trips both locally and overseas. Other students participated in student-run engineering clubs that carried out tutoring activities at local schools. Official service opportunities for engineering students began in the 2008 through the introduction of the student-formed LMU Engineers Without Borders (EWB) chapter. Their first extra-curricular project based in Malawi inspired the college to explore other ways to integrate the service aspect of the University's mission into the engineering programs.

This paper focuses on both extracurricular and curriculum-based service opportunities that have developed over the past six years for engineering students at LMU. Two case studies describe extracurricular international service projects aimed at assisting rural communities in need of clean water. We highlight key aspects of the Malawi project as well as another water treatment project carried out with an island community in El Salvador. Two other case studies highlight the curricular service-learning experiences that students engage in locally. The engineering programs now offers two curriculum-based service opportunities where students can

receive academic credit. The first, introduced in 2009, is a living-learning community (LLC) where freshman students live together and take an introductory engineering course together that includes a project-based service component. The second and more recent opportunity involves designing assistive devices that promote learning and increased independence for K-8 students with disabilities who attend a local charter school. Outcomes produced and lessons learned by our experiences in advising students on these projects are emphasized in the paper.

CASE STUDIES: EXTRACURRICULAR INTERNATIONAL SERVICE PROJECTS

In this section, we describe the two extracurricular international service projects performed in Malawi and El Salvador. As the lack of access to clean water in much of the economically developing world remains one of the primary causes of mortality in children⁵⁻⁶, the objective of these two projects was to provide access for potable water to both communities.

Malawi Water Project: Malingunde School for the Blind

The LMU-EWB student chapter was formed in 2008 and soon began plans for their first international service project based in Malawi, Africa. The objective was to provide potable water to the Malingunde School for the Blind (MSB) and the neighboring health center and community. The students established the MSB as the site based on a relationship formed with the Lilongwe Rotary Club (LRC) through a family connection of one of the students.

To foster a relationship with the Rotary Club, MSB, local church leaders, and the Lilongwe Water Board (LWB), we performed an initial weeklong assessment trip with an LMU team comprised of one faculty member and three engineering students. The team spent considerable time with the children, faculty, and staff from the school to establish trust and understand their needs. We made a considerable effort to experience and better understand the culture and customs in Malawi. For example, we attended LRC meetings and held conversations with locals. In addition, we collected relevant water source quality and topographic data. This assessment trip, required by EWB, proved to be valuable in the project's success.

Prior to the assessment trip, the team, based on preconceived knowledge and conversations with LRC members, expected that a borehole to the local groundwater would provide the best means for MSB to obtain potable water. We learned from MSB board members, however, that two boreholes had been implemented in the past and failed shortly after due to seasonally varying water table depth and lack of community understanding of how to maintain the pump. More specifically, MSB board members told us that a large non-governmental organization (NGO) drilled the boreholes and provided hand pumps without performing any rigorous assessment of the site. Furthermore, the community was not involved and operation and maintenance instructions were not provided. Hence, upon failure, the community was not able to fix the wells and they became inoperative. Based on these interactions, it became clear to us that the community needed to be empowered in the decision-making process and involved in the implementation of the project. This way, when maintenance is required and malfunctions occur, the community would feel a sense of ownership and be able to perform the required tasks. In the end, based on meetings with MSB board members and LWB, we decided to implement a pump and treat system using source water from the local reservoir and the existing LWB pump house and infrastructure. Although the specific type of treatment system and the details of the design were essential for the project's success, these were not determined during the assessment trip.

Between the assessment and implementation trips, members of the MSB and LWB, several LMU students, two LMU faculty members, and two outside water experts were all involved in deciding the best way to supply potable water to the community. Based on these interactions, it was decided to construct a slow sand filtration system due to its simplicity, reliability, and ease of operation and maintenance. Other disinfection methods were also considered, however, LWB indicated that they preferred not to have chemical treatment (e.g., chlorine) due to taste concerns and operational issues, or treatment requiring additional energy (e.g., ozone). The final design called for the upgrade of severely damaged existing water pipes, the replacement of a broken pump's shaft impeller, the addition of two 5,000 liter parallel filters below an existing 25,000 liter holding tank, and two 5,000 liter tanks below the filters to store the treated water for the school and the health center. The system was constructed to meet the needs of approximately 125 to 250 people, assuming 40 liters per capita per day of water demand. As this project was in line with LWB's philanthropic mission to serve potable water to communities in need, they agreed to finance the project's operation and maintenance costs, including electricity to power the pump, purchasing replacement parts, and providing a daily pump operator.

The design process took considerable time partly due to substantial email response time delays with our Malawi partners. Initially it was tasked to the students to perform such communication, however, it was later determined that it was more efficient to have the lead faculty member handle communication. While the students led the primary design, we learned that faculty and professional support and expertise were essential in the process. In fact, due to this expertise, we decided to perform the review process and implementation trip independently of EWB in order to save on the required EWB fees.

It took two years for the college to secure trip funds from donors, a university led proposal to the Allergan Foundation, and a student led proposal with the support of a faculty member to the World Water Forum. The timing of the rainy season made roads to the village impassable during winter (boreal) break requiring that we implement the trip during the summer break. As a result, we planned implementation in close coordination with the Malawi partners during the summer of 2011. Shortly after, however, the LRC suggested the postponement of the trip due an unexpected political regime change making the region potentially unsafe. Finally, in the summer of 2012, three years after the initial assessment trip, a second LMU team composed of six new students from a mix of undergraduate levels, one faculty member, and one water system expert traveled to Malawi to install and implement the pump and treat system.

While we expected implementation to take less than a week, we planned for two weeks in case of unforeseen problems. In the end, the two-week implementation trip had to be extended by an additional three days. During implementation, two engineers from the Lilongwe Water Board aided the team, which proved to be critical for the project's success. Numerous unforeseen problems arose during implementation resulting in delays. For example, a general lack of availability of imported goods due to recent foreign exchange rate issues made it impossible to find a new pump to transport water from the reservoir to the holding tank. In addition, the sand and gravel for the system that were to be collected from the shores of Lake Malawi did not arrive until the second to last day of the trip due to a disagreement between LWB and local chiefs.

Local support from the Lilongwe Rotary Club, the Lilongwe Water Board, and a local community church was essential for the success of this project. The project would have failed without the collaboration and support of any one of these entities. To help ensure the long-term sustainability of the project, we trained the LWB team and pump operators and provided them with an operation and maintenance manual. The LWB indicated in a recent email that the system

is “working perfectly and that there was more than enough water at the school, pastor's house, church, and the clinic.” Both upper administrative support from LMU and donor financing greatly contributed to this project's overall success. However, the majority of the trip's expenses were spent on travel, as it is relatively expensive to travel from the United States to Malawi. While Africa is the poorest continent and can therefore greatly benefit from such projects, the high travel costs bring into question the cost/benefit compared to other regions, such as Central America. Nevertheless, we continue to maintain our partnership with the LWB and LRC and the LMU-EWB group is currently considering a second project with them.

El Salvador Water Project: Isla El Espiritu Santo

Since 2011, LMU students began visiting a remote island in El Salvador called Isla El Espiritu Santo as part of the university-sponsored Campus Ministry trips. These faith-based immersion trips focus on the connections between faith, social justice, and community, and were not explicitly intended to be an opportunity for hands-on engineering learning. However, after the first trip in 2011, one of the participating engineering students observed many concepts from her civil engineering curriculum that could aid the community and its need for safe potable water. Over the next two years, this student spearheaded the campaign to return to El Salvador to implement a water improvement project. She worked closely with the Campus Ministry office to plan subsequent trips, maintained contact with the community leaders in El Salvador, and even recruited faculty from across the college to participate in various aspects of the project. Two additional Campus Ministry trips and one college-sponsored trip, funded by college donors and a grant from the World Water Forum, took place between 2011-2013.

During the initial visit, the LMU delegation developed a relationship with a local NGO, Centro de Intercambio y Solidaridad. The NGO's staff helped facilitate conversations with the village leaders about the need to access clean water in the community, implement safe water practices, and consider the observations the students were making during their visit. The students collaborated with the NGO to conceptualize a water treatment/distribution project. The student leaders and the community partner coordinated via email in order to plan the next trips. The 2011 summer trip involved the installation of a new water pump at a school in El Espiritu Santo. By connecting to the village's only well, the school now has more reliable and better access to water. To address water quality, the team distributed simple tabletop water filters for households to reduce the risks related to water contaminated with pathogens. The students facilitated educational workshops with community members to introduce the water treatment process and teach them how to use and care for their household filters. This initial trip, consisting of six engineering students and a faculty member, set the foundation for collaboration among LMU engineering students and the El Espiritu Santo community. The undergraduate student who had spearheaded the clean water project remained in El Salvador for the summer as a volunteer teacher. She also served as a liaison to building the momentum for the water treatment program and maintaining rapport and trust with community leaders. The same student returned once again, leading a new Campus Ministry trip in the spring of 2012, which included 12 students and a different faculty member. The Campus Ministry trip continued the partnership with the local NGO and the community members to solidify our commitment toward the project.

In the winter of 2013, another engineering student group returned to El Salvador to continue the work of the project, which required additional planning, fundraising and the recruitment of new team members since many of the student participants graduated. This trip took place in

January 2013 with nine engineering undergraduate students and a faculty member. During this trip, the delegation installed a ultra-violet filtration system at the village clinic, modeled after the one installed at the school during the previous trip. As a sign of solidarity, community members assisted with the manual labor, working hand-in-hand with the students to dig a 600-meter long trench for piping. The combination of outside support and proper training of the community have succeeded in maintaining the proper operation of the water treatment and distribution system.

To expand the water treatment component of the project, more families received filters for their homes. Some families had their existing filters replaced, which was expected given that the families had limited experience using the filters properly. As in the previous trip, students led educational workshops to inform the community about the filter kits and how to properly use and maintain the filter to treat their drinking water. In addition, the 2013 delegation incorporated bacterial testing to evaluate the village's well water conditions as well as the effectiveness of the household filters. High levels of *E. coli* counts indicated widespread contamination in the surface wells that the community depends on as its main potable water source. The students shared the results from the bacterial testing at community forums to reiterate the importance of clean water and proper filter use, and to begin conversations about the factors that cause contamination. Members of the community members were able to visually see the results, learn, and engage in candid dialogue. Many of the engineering students attribute the improved communication to the rapport they built by staying with host families and engaging in social activities with other community members.

Another dimension of the 2013 trip incorporated an academic dimension when a subset of students decided to focus on the island's waste and wastewater treatment for their senior capstone project. They collected data to assess soil conditions and to create a topographic map of the area. They presented their preliminary findings and initial plans at our university's Undergraduate Research Symposium and at a special presentation within the college.

Due to LMU's continual involvement with this community partner and multiple site visits, the filtration systems at the clinic and school at Isla Espiritu Santo are operational and provide clean water to over 300 families on the island. However, the main challenge of this project is the lack of a current project leader. In many ways, the one undergraduate student dedicated her time to hold the project together, while all other participants, including faculty members and staff within different campus offices, only knew bits of information about the overall project. Although a number of faculty contributed to the project, none identified themselves as the faculty advisor to oversee the planning, communications, and all other logistical aspects associated with sustaining an international project. Once the student graduated, and other personnel shifted at LMU and within the NGO in El Salvador, momentum for the project slightly diminished with no clear leadership or plan to move forward. In order to provide improved continuity, the LMU-EWB group is planning to take over planning future projects with the local NGO and community members in El Salvador.

A summary of the main challenges associated with each of the two highlighted international service projects and our responsive actions are summarized in Table I.

TABLE I
MAIN CHALLENGES WITH THE EXTRACURRICULAR INTERNATIONAL SERVICE PROJECTS

Case Study	Main Challenges	Responsive Actions
Malawi Water Project: Malingunde School for the Blind	<ul style="list-style-type: none"> • Costly Engineers Without Borders (EWB) fees and high travel costs to Africa • Additional time was needed for implementation of the project beyond the allotted two weeks 	<ul style="list-style-type: none"> • Performed review and implementation independently of EWB (with sufficient faculty and professional support and expertise) in order to save on the EWB fees • Extended the implement trip by an additional three days
El Salvador Water Project: Isla El Espiritu Santo	<ul style="list-style-type: none"> • Lack of a continuous faculty project advisor • Project was held together by an undergraduate student 	<ul style="list-style-type: none"> • Working with the LMU-EWB group to take over and manage all future projects • Developing processes at the college level to support international service projects

CASE STUDIES: COURSE-BASED SERVICE-LEARNING

In addition to the international engineering service projects, LMU engineering students have the opportunity to be involved in various service-learning projects through some of their courses. First-year engineering students have the opportunity to participate in a service-oriented living-learning community (LLC). Other first-year engineering students and senior mechanical engineering students have been involved in projects developing assistive devices for children with disabilities at a local public charter school.

Program for an Engineering Education Community (PEEC): A First-Year Engineering Student Living-Learning Community

In 2009, the Dean of the College of Science and Engineering and the LMU-EWB faculty advisor developed a living learning community for first-year engineering students where participants live together and engage in two common engineering courses during their first year. This LLC was formally named Program for an Engineering Education Community (PEEC). Based on the experience with the LMU-EWB chapter, we recognized the value for students to engage in engineering related service projects and made it a requirement of the PEEC program. The program is designed with a 3-credit introduction to engineering course in the fall semester followed by a 1-credit course in the spring, with the intention that the service project planning occur in the fall and implementation in the spring. The program is limited to about 25 students per year and has reached full capacity every year. Students are selected for the program based on interest and to create as much academic, ethnic, and gender diversity as possible.

Six student cohorts have participated in the PEEC program since its inception. Table II shows a summary of the wide range of projects and community partners. Although the first PEEC cohort planned out four different projects, only the high school lesson plans were actually implemented. The low implementation rate was mostly due to the fact that this was our first time running the program and difficulties arose in planning and coordinating the several projects with first-year engineering students in such a short period of time. Based on this experience, we decided that it would best for each subsequent cohort to focus efforts on one large project in

partnership with one group. Not only does this increase the probability of success, but it also allows us to develop an in-depth sustainable relationship with a single community partner.

The primary focus of our PEEC program discussion is on the projects and lessons learned while working with a non-profit transitional residence that provides safe and supportive housing for women and children in the process of moving from emergency shelter to permanent housing. Three PEEC classes (2009, 2010 and 2012) have been involved with service activities at this transitional residence, and other LMU groups continue to perform service there. After the initial planning efforts from the 2009 PEEC class for a playground, which was identified as a priority by community partner, the 2010 class continued working on the project. The students successfully installed the playground in the summer of 2011. As part of the design and implementation process, students worked directly on cost estimating, comparison of alternatives, surveying, drainage, and installation of the playground. Upon completion, the students gave a presentation of this work at the LMU Undergraduate Research Symposium. In addition to the playground project, students engaged in non-engineering activities with the women and children from the shelter, including setting up garage sales, tutoring, cooking, and cleaning. These activities helped our students directly engage with the shelter residents.

TABLE II
SUMMARY OF THE FIRST-YEAR ENGINEERING STUDENT LLC PROJECTS

Cohort	Engineering Service Project
2009	<ol style="list-style-type: none"> 1. Developed and delivered engineering lectures and lessons for local high school students 2. Designed inexpensive portable lighting alternatives for African children to study at night 3. Planned the design of a playground at a transitional residence for women 4. Planned a greywater irrigation system at a transitional residence for women
2010	Planned, designed, and installed a playground at a transitional residence for women
2011	Conducted water quality and hydrologic studies for the Santa Monica Bay Restoration Commission
2012	Planned, designed, and installed a greywater irrigation system at a transitional residence for women
2013	Designed and implemented engineering lessons for students at a local K-5 public STEM school. Projects included windmills, sailboats, various model cars, and water filters.
2014	Developed new engineering lessons plans and design competitions for students at a local K-5 public STEM school. Projects included solar cars, water filters, and a geothermal plant.

The continuous engagement with the women at the transitional residence helped gain the community's trust and better understand its needs. Faculty members were initially in charge of communication, but students gradually began to take increased responsibility in organizing visits. Maintaining such continuity, however, is challenging; the projects require considerable commitment from the already busy students and faculty. Integrating such projects into the course curriculum, however, allows students to perform service and simultaneously meet the course objectives, thus reducing the overall time commitment.

The 2012 cohort of PEEC students maintained our commitment to the transitional residence for women through the design and implementation of a greywater subsurface irrigation system using water from their heavily used washing machine. Turf landscaping in the front of their two houses demanded considerable irrigation costs. Hence, a greywater system would greatly reduce their water bill. The project required that the students understand health issues concerning greywater, filtration, piping systems, and landscape watering requirements. The project was funded by the university's Center for Service and Action through the efforts of two upperclassmen. The upperclassmen students and other groups provided much needed assistance to the PEEC students with knowledge, experience, transportation, and other logistics that the project required. For example, a water systems expert from a local environmental engineering firm and several members from the LMU student chapter of the American Society of Civil Engineers helped the PEEC team install the system. Thus, the curricular first-year engineering project required considerable assistance from outside groups. Of particular note, the university recognized the two upperclassmen students on the team with an award for their efforts.

Course evaluations and interviews with former PEEC students have shown that the program has been successful in terms of providing the students with a sense of accomplishment in applying engineering concepts while helping the community. However, implementing the engineering projects has proved difficult. For example, the multiple needs from the community partner demanded considerable time from our students and faculty who have other academic and additional extracurricular commitments. This was first evident in the playground project, which required two years to complete and was only possible with help from other engineering student clubs. The greywater system was an even more complex project, which required considerable logistics and time in the design, procurement and installation of the pump and filter station, significant electrical and plumbing work, trenching of the irrigation system, and support during implementation from upper-division engineering students and an outside engineering firm. Furthermore, transportation of first-year engineering students to the off campus site was difficult.

Over the past three years, due to a lack of identified projects from the transitional residence, the PEEC students have worked with other community partners. For example, the two most recent PEEC cohorts have worked on developing engineering lesson plans, projects, and design competitions for a local STEM-focused K-5 public school. This shift toward working with other partners has created some difficulty in maintaining continual engagement with the transitional residence for women. For example, we were recently informed that the playground set needs to be replaced due to termite problems and that the greywater irrigation system pump was no longer working. The LMU-EWB students have recently committed to providing continued support to the transitional residence for women, including replacing the playground swing set, fixing the pump, and providing math and science tutoring for the resident's children. To better ensure a long-term commitment, we have strongly encouraged that the LMU-EWB group combine these efforts with LMU student chapters of the Society of Women Engineers, National Society of Black Engineers, and Society of Hispanic Professional Engineers.

Partnership with WISH Charter School: Design of Assistive Devices

Another curricular-based approach to engage engineering students in service-based learning was initiated by an LMU engineering faculty member and involves a close partnership with the Westside Innovative School House (WISH), a public K-8 charter school that is dedicated to providing an inclusive educational environment for all children. In a full inclusion setting,

students with special needs are educated alongside students without special needs while maintaining appropriate support and services. LMU engineering students have been designing assistive devices for students at WISH Charter since the fall of 2012. Teams of mechanical engineering students annually complete these projects for their yearlong, two-semester senior capstone design project course sequence. Recently, first-year engineering students not participating in PEEC have also started working on projects in partnership with WISH Charter as part of their first-year introduction to engineering course. Since 2012, approximately 40 students and two engineering faculty have been involved with the projects at WISH Charter. The school is conveniently located less than one mile from the LMU main campus, making transportation very easy. The LMU engineering student teams are put directly in contact with a teacher or staff member at WISH Charter in order for them to best scheduling site visits.

The first assistive device design projects that our engineering students completed began in the fall of 2012. Overall, the projects were highly successful in terms of meeting the design requirements. One team even placed third at the 2013 RESNA Student Design Competition (RESNA = Rehabilitation Engineering and Assistive Technology Society of North America). The devices, however, were not viewed to be highly important or useful to the K-8 students by their parents and the staff at WISH Charter who better understand the needs of the children. This experience brought to light the importance of first starting out by empathizing with our partnering organization and truly understanding their specific priorities and needs.

As a response, LMU faculty brainstormed with teachers and staff at WISH Charter over a series of meetings during the summer of 2013 and created a prioritized list of project ideas that were identified to be of a high priority for the students with disabilities (Table III). In total, a list of more than 30 different design projects was generated, all ranging in levels of complexity. The staff, teachers, and parents of children with disabilities at WISH Charter have access to this document and can add their ideas to it at any time. Both our community partner and our faculty advisors can continually access and update the document.

TABLE III
EXCERPT FROM OUR COMMUNITY PARTNER WISH LIST

Project	Detailed Description	WISH Priority	LMU Status
Desk Stander	Portable stander that can be attached to any table in order to provide standing support for the student	Highest	In testing
Assistive Tricycle	Supportive, assistive tricycle for a student with Cerebral Palsy	Highest	In development
Desk Modification	Modification of an existing combination desk with an attached chair to support student	Highest	Not started
Fidget Chair	Chair to allow students to fidget, yet remain in their seat	High	In development
Writing Guide	A slanted board to help students write within a confined space	Medium	In testing
Sensory Board	Different types of surfaces items for students to touch and interact with	Medium	In testing

Before beginning a new design project, LMU engineering students are first required to make multiple trips to the WISH campus and spend time with the students, teachers, and staff. The intention is that our students must first empathize with our partner and build a relationship with them before starting a project. As a form of outreach, our students are encouraged to include the K-8 WISH students in the design process as much as possible. Furthermore, our students are challenged to maintain a mindset that they are designing the assistive devices *with* the students for disabilities, not simply *for* them.

Our most recent design projects are focusing on developing solutions that address the highest needs of our partners at WISH Charter. For one of these projects, we were asked by one of the students' parents to develop an assistive stander for her son that could be easily transported and attached to any desk or table. Standing is crucial to the physical rehabilitation of many people with disabilities, as it provides an alternative for positioning and pressure relief. The device previously used to help this student stand during his various activities is a pediatric stander that is weighted down with sandbags. The device was bulky, separated the student from his classroom peers, and limited the types of tables he could stand at. A team of senior mechanical engineering students designed a compact, portable stander that is now used by the student both at home and at school. The current stander directly promotes inclusion, as the student is able to stand at the same table as his peers. The standing device was extremely well received by the student, his parents, and WISH Charter. The parent currently takes the device to and from school daily and has asked us to make them at least one more that can be kept at home. WISH Charter also asked us to make more of these standers for other students.

Due to a strong interest from our students in working on these projects with WISH Charter, we are exploring ways to provide additional opportunities for our students to work on these projects throughout their undergraduate program. For example, a non-PEEC section of introduction to engineering course was restructured to include a semester-long engineering-focused project in partnership with WISH Charter. Nine teams with about four students per team worked with an individual classroom at WISH Charter. Teams designed engineering lesson plans, activities, demonstrations, and low-tech assistive devices for some of the WISH Charter students. We are currently working closely with the LMU-EWB group in order to further enhance our partnership with WISH Charter and to offer extracurricular project opportunities.

A summary of the main challenges associated with each of the two highlighted international service projects and our responsive actions are summarized in Table IV.

TABLE IV
MAIN CHALLENGES WITH THE COURSE-BASED SERVICE-LEARNING PROJECTS

Case Study	Main Challenges	Responsive Actions
PEEC: A First-Year Engineering Student Living-Learning Community	<ul style="list-style-type: none"> • Planning and coordinating with inexperienced first-year students • Tight project schedule • Maintaining continuity with community partner 	<ul style="list-style-type: none"> • Focused on working on one project with a single community partner at a time • Cooperated with other supporting groups (e.g., upperclassmen students and student engineering organizations)
Partnership with WISH Charter School: Design of Assistive Devices	<ul style="list-style-type: none"> • Initial assistive devices were not viewed highly important or useful by our community partner 	<ul style="list-style-type: none"> • Conducted stakeholder brainstorming to identify most important needs • Created a prioritized list of project ideas that is updated by our community partner

OUTCOMES AND ASSESSMENT

Although we have not conducted formal assessment of our extracurricular international service projects, we have begun to assess the course-based service-learning projects. The PEEC program has been valuable in providing first-year engineering students with the opportunity to participate in a service-focused engineering living-learning community. Interviews and surveys with PEEC students have revealed that they appreciate living together because it allows them to better focus on their coursework and helps them in forming long-lasting friendships. Many of the PEEC students continue to live together until they graduate. For example, over 50% of the 27 students in the 2010 PEEC cohort were still roommates when they graduated in 2014. During our interviews, students indicated that they gained practical engineering knowledge and a sense of accomplishment as they participated in the service projects that promote the university's mission of social justice. Presentations of the service projects at student conferences and tours of engineering companies further enhance the experience. Conversely, the PEEC students have also identified several areas that require improvement. These include improvements in organization, logistics, the high time and workload demands on first-year students, and the need to nurture ongoing partnerships with the serviced communities.

In terms of the WISH Charter projects, a recent exploratory, pilot study was conducted that focused on gathering and evaluating reflections from the mechanical engineering senior students working on the assistive device design projects⁷. In particular, the students responded to four open-ended post-intervention questions regarding their perceptions of working on such projects:

1. How did your project impact your development as a professional?
2. How did it impact your development as a member of society?
3. What did you learn from your project in regards to human needs, especially for those with disabilities?
4. How did this project affect your future career plans?

These questions were designed to identify general conceptions of student learning and development as professionals and as general members of society. An open-coding approach was taken to identify emergent categories in the data. All of the participating students reported an increased motivation and a desire to use their engineering knowledge to help others. However, it was unclear whether this experience actually caused this increased motivation or if their participation just enhanced an existing latent desire. Most of the students indicated that these service-learning projects helped with their development of teamwork and communication skills, and increased their empathy of persons with disabilities.

We recently began using a mixed-methods approach to assess the impacts of the course-based service-learning projects on our engineering students. The assessment instrument has three main areas:

1. We are quantitatively measuring changes in engineering design self-efficacy using a previously validated instrument⁸. Self-efficacy, or an individual's confidence about their ability, is shaped by experiences, persuasions, and physiological states⁹. The inclusion of a measure of engineering design self-efficacy will provide a gauge of how the service-learning projects impact student confidence in conducting various engineering design tasks.

2. We are also quantitatively measuring students' perceptions as to how the projects impact their development of both technical-engineering design subject-matter knowledge and professional-personal skills using a modified version of the validated National Engineering Students' Learning Outcomes Survey (NESLOS) instrument¹⁰⁻¹³.
3. Finally, we are collecting student reflections regarding what they learned in terms of their personal development, the social impacts of their projects, how their experiences enhanced their academic experience, and what they learned in terms of professional ethics. Critical reflection is an integral component of service learning, as it requires students to evaluate the connections between their service experience and the overall learning outcomes goals. In particular, we are asking students to reflect on personal development, social impact, academic enhancement, university mission, and ethics¹⁴.

Pre and post assessments will be conducted annually of all students participating in our course-based service-learning projects. Throughout our assessment, appropriate information will be collected to monitor if differences arise between students grouped by certain demographic and academic factors. Finally, we are also planning to collect overall feedback from our community partners by having them complete a survey adapted from the Customer Satisfaction Questionnaire (CSQ) assessment instrument¹⁵. The survey will focus on various constructs, including quality, cost-benefit, involvement, complexity, deliverables, and overall client satisfaction.

In the future, we will expand our efforts to also assess our extracurricular international service projects. We hope that our efforts will lead to standard and formalized assessment procedures for all of our future engineering-oriented service projects.

OVERALL LESSONS LEARNED

Since 2008, LMU engineering students can now participate in extra-curricular international service projects and local course-based service-learning projects. It is our intention to determine how we can best optimize these experiences while also considering our institutional mission. The main challenges associated with our highlighted case studies and our responsive actions were presented in Tables I and IV. As a result of critical analysis and reflection by the primary faculty and staff members involved in arranging and advising these projects, the following overall lessons have emerged:

1. *Students should receive course credit for participating in engineering-oriented service projects.* In addition, advising such projects should be counted toward the teaching course load for faculty members. Extracurricular projects can be beneficial, but students and faculty should not be expected to participate in such projects on top of their normal workloads. Students and faculty at LMU are interested in pursuing these projects, and it would be best if they receive appropriate credit for doing so. Tying service-oriented projects to a course creates more accountability for the students to complete their responsibilities and generates incentive for both students and faculty to be dedicated to the success of the project.
2. *Opportunities for student participation should be vertically integrated throughout the curriculum.* In order to improve continuity within projects and the overall long-term

sustainability of community partnerships, students at any level should be able to participate in engineering service-learning projects. Many faculty at LMU are currently interested in offering service opportunities in their courses, but only first-year engineering students and senior mechanical engineering students have had the opportunity to receive course credit for service-learning projects. The problems that we are currently facing is that projects need to be restarted after the seniors graduate and sophomores and juniors that want to continue working on their first-year engineering projects are often too busy with their course loads.

3. *Develop and sustain long-lasting relationships with your community partners.* We realized that we must empathize with and understand the specific needs of our community partners. Working on projects that are not of a high priority to them is not an efficient use of resources. We have learned that it is important to start small and work with a single community partner and develop a solid relationship before branching out and trying to develop other partnerships. For local partnerships, it is important to consider the proximity of your partner. We suggest having both your academic institution and your community partner commit to building a long-term relationship over many years. It is important that not a single individual, but a continuous team of faculty, staff, and students work to maintain the relationship with your community partner. Developing relationships with other community partners is not discouraged, provided the resources and ability are available, but it should not be done at the expense of existing partnerships.
4. *Obtain university support for long-term success.* While the aforementioned projects have all been driven primarily by faculty and student interest, university support has been required for their success. In all of the occasions, the college has provided substantial financial support when needed. For example, two thirds of the funding for the Malawi project was secured from college donors and a grant written by the university's Corporate and Foundations Office. In addition, the college initiated the PEEC program and the LMU's Center for Service and Action funded the implementation of the greywater irrigation project. College level support has also been demonstrated at annual college faculty meetings, where the PEEC program and the WISH Charter projects have been highlighted.
5. *Start to conduct assessment of your stakeholders.* When LMU students first began participating in engineering-oriented service projects, we did not conduct any formalized assessment. We have recently recognized the importance of assessing participating students, faculty advisors, and community partners. We now view assessment as essential for finding ways to maximize the overall benefits of these projects and to validate the advantages of service learning within engineering education. It is important to start small with your assessment methods in order to not become overwhelmed, but you should do something. We have found it to be very important to include ways to obtain quick and immediate feedback from our community partners. With regard to our students, we are taking active steps to now formally assess the impacts of the course-based projects on our students and we plan to expand this assessment to include the impacts of extra-curricular activities.

6. *Utilize the resources at your institution in order to promote cooperation.* We recognize that each institution is unique and will have its own strengths and challenges. On two occasions, we partnered with the School of Film and Television to assist with public awareness of our engineering service projects. Since one of the objectives of the Malawi project was to broaden awareness of the global water crisis, an LMU film student accompanied them to document the installation of the pump. Likewise, one of the WISH Charter design projects was featured in a short documentary film, which has been licensed by Shorts HD and is scheduled to appear in a promotion package for DirectTV. Working across the university presented a mutually beneficial learning experience for LMU students across the disciplines. We also recognize that in order to create sustainable service-learning opportunities for our engineering students, we must encourage our different groups to cooperate. For example, we are working to encourage our LMU-EWB organization to increase their efforts to team up and establish formal collaborations with other LMU student engineering clubs and LMU's Center for Service and Action and Campus Ministry offices.

Other authors have discussed many of these lessons learned within the engineering service-learning community. We realize that the long-standing successful programs, such as EPICS, SLICE, EWB, and ESW, have similar recommendations based on their decades of experience. Again, the main challenge lies in how to best emulate these highly successful and long-standing programs in the unique setting of each academic institution. We present the lessons that we have learned over the past six years at a primarily undergraduate liberal arts institution in the Jesuit and Marymount traditions. We hope that our specific cases studies are helpful to other universities in implementing service-oriented engineering projects.

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